

RESEARCH ARTICLE

Social perspectives on the use of reference conditions in restoration of fire-adapted forest landscapes

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As approaches to ecological restoration become increasingly large scale and collaborative, there is a need to better understand social aspects of restoration and how they influence land management. In this article, we examine social perspectives that influence the determination of ecological reference conditions in restoration. Our analysis is based on in-depth interviews with diverse stakeholders involved in collaborative restoration of fire-adapted forest landscapes. We conducted interviews with 86 respondents from six forest collaboratives that are part of the U.S. Forest Service's Collaborative Forest Landscape Restoration Program. Collaboratives use a variety of approaches to develop reference conditions, including historic, contemporary, and future scenarios. Historical conditions prior to European settlement (nineteenth century or "pre-settlement" conditions), or prior to more recent grazing, logging, and exclusion of fire, were the predominant type of reference used in all sites. Stakeholders described benefits and limitations of reference conditions. Primary benefits include (1) providing a science-based framework for bringing stakeholders together around a common vision; (2) gaining social understanding and acceptance of the underlying need for restoration; and (3) serving to neutralize otherwise value-laden discussions about multiple, sometimes competing, resource objectives. Limitations stem from (1) concerns over social conflict when reference conditions are perceived to contradict other stakeholder values and interests, (2) differing interpretations of reference condition science, (3) inappropriate application or over-generalization of reference information, and (4) limited relevance of historical references for current and future conditions in some ecosystems. At the same time, collaboratives are adopting innovative strategies to address conceptual and methodological limitations of reference conditions.

Key words: fire-prone forests, historical ecosystem, landscape restoration, pre-settlement, reference models, restoration goals, stakeholder collaboration

Implications for Practice

- Diverse stakeholders identify common benefits and limitations of varying approaches to ecological reference conditions (including historical, contemporary, and future scenarios) and negotiate trade-offs among sources of information to guide collaborative restoration in fire-adapted forest ecosystems.
- Despite long-standing debates over the relevance of historical information as models for current and future landscapes and climates, our results suggest that historical reference conditions continue to play an important role in social understanding and perspectives on restoration.
- Collaborative groups have adopted strategies to address limitations of reference conditions such as integrating information about past, present, and anticipated future conditions, identifying reference periods that are analogues to current and projected future climate, and balancing science-based targets with other social values in restoration planning.

interest groups, and agencies at all levels of the process (Higgs 1997). Thus, there is a pressing need to better understand social perspectives on restoration and how they influence land management. In this article, we examine social perspectives that influence the determination of ecological reference conditions in restoration. Multiple sources of information can be used to describe reference conditions including historical, present, and future conditions. The choice of information, however, is a subject of debate (Thorpe & Stanley 2011; Higgs et al. 2014). Managers must identify various benefits and limitations to reference conditions and negotiate trade-offs among sources

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Introduction

Approaches to ecological restoration are increasingly large scale and collaborative, involving a broad array of communities,

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of information in the context of changing landscape conditions and potentially competing societal preferences. Despite a growing scientific literature on reference conditions, limited attention has been devoted to how resource managers and the public identify and agree on reference conditions to guide restoration. Here, we report on strategies used to establish reference conditions in collaborative restoration of fire-adapted forest ecosystems. Our analysis is based on in-depth interviews with diverse stakeholders from six collaboratives in the western United States, part of the Collaborative Forest Landscape Restoration Project (CFLRP), a policy initiative designed to support collaborative decision-making in the management of U.S. Forest Service lands.

Ecological reference conditions are prominent in the science and practice of restoration by serving as targets for planning projects and establishing criteria for measuring success (SER 2004; Keenleyside et al. 2012; McDonald et al. 2016). Reference conditions are, by definition, an approximation of a focal ecosystem in the absence of damage or degradation (McDonald et al. 2016). Because it may not be possible to know the condition of an ecosystem prior to damage or degradation, reference conditions are determined from the best available information (White & Walker 1997; Keenleyside et al. 2012). There is a tradition of using data on historical conditions or the “historical range of variability” as reference information to guide restoration (Landres et al. 1999; Wiens et al. 2012; Higgs et al. 2014). The rationale for using historical conditions is that they represent the structure, composition, and/or function of an ecosystem prior to significant industrial human influence (Keane et al. 2009). However, the dynamic nature of some ecosystems, coupled with current and anticipated future effects of climate change, human-land use, and biological invasions, may limit the relevance of historical references (Hobbs et al. 2014; Perring et al. 2015).

Other types of reference information used to set restoration targets include contemporary, relatively undisturbed systems and the results of predictive models of future conditions (e.g. scenario planning or “future reference conditions”) (Keenleyside et al. 2012; McDonald et al. 2016). These approaches can be combined with historical references in restoration planning (Schoennagel & Nelson 2011). In addition, some managers are interested in setting restoration targets based on desired ecosystem functions (Thorpe & Stanley 2011; Laughlin et al. 2016). Each of these approaches has benefits and limitations. For example, historical references can provide useful targets for management by identifying explicit sets of conditions that supported desired ecosystem functions for long periods of time that included frequent disturbance and fluctuations in climate (Franklin et al. 2013). However, the practice of choosing a historical time period as a reference has been criticized as reinforcing the view that ecological systems are static or in equilibrium (Moore et al. 1999). Alternatively, contemporary reference systems provide information about undamaged ecosystem patterns and processes that are feasible in current landscapes. Given the extent of habitat transformation and fragmentation, however, appropriate references can be difficult to identify (Safford et al. 2012). Although future reference conditions can help to inform

ecosystem management in the face of changing climate and disturbance regimes, projections of future conditions are uncertain (Lawler et al. 2010).

Restoration of fire-adapted forests is a management priority in many parts of the world (Rodríguez-Trejo & Fulé 2003; Fulé et al. 2008), including the western United States (Covington et al. 1994; Noss et al. 2006; Hessburg et al. 2015). Here, long-term fire exclusion, grazing, and logging have increased the density of shade-tolerant and fire-intolerant species in historically fire-adapted forests and, often, the density and connectivity of fuels (Covington & Moore 1994; Hessburg & Agee 2003). In turn, these changes in forest structure have increased risk of insect outbreaks, stress-induced tree mortality, and wildfires, with potentially profound ecological, human health, and economic consequences (Franklin et al. 2014). Furthermore, projections of drought stress associated with climate change suggest greater vulnerability of these systems to fires of greater size and severity (Millar et al. 2007; Littel et al. 2009).

Restoration treatments in fire-adapted forests include mechanical thinning of younger and smaller diameter trees, prescribed burning and, occasionally, managed wildfire (Allen et al. 2002; Agee & Skinner 2005; Schoennagel & Nelson 2011). Restoration targets often focus on the structural elements of forests, such as the size distributions of trees, stem densities, and spatial patterning (e.g. size or spacing of clumps and nonforested openings; Harrod et al. 1999; Larson & Churchill 2012). At a landscape scale, restoration targets include spatial heterogeneity of forest structures indicative of the disturbance patterns that created these structures (Hessburg et al. 2015). An underlying assumption of these treatments is that by restoring forest structure and landscape pattern, related ecosystem characteristics (e.g. native biodiversity, resilience to disturbance) are also restored (Stephenson 1999; Hessburg et al. 2015).

Restoration of fire-adapted forests faces the complex challenge of competing societal values and goals, particularly on public lands (Brunson & Shindler 2004; Fischer et al. 2016). For example, in the western United States, the pace and extent of restoration have been hindered by debates about the effects of treatments on wildlife habitat and biodiversity, community health and wildfire safety, recreational values, and timber resources (McCaffrey et al. 2013; Franklin et al. 2014). In 2009, the U.S. Congress passed the Forest Landscape Restoration Act (FLRA), which allocated funds to establish the Collaborative Forest Landscape Restoration Program (CFLRP) on U.S. Forest Service lands in fire-adapted forest landscapes (Schultz et al. 2012). The purpose of the CFLRP is to support “collaborative, science-based ecosystem restoration of priority forest landscapes through a process that encourages ecological, economic, and social sustainability ...” (Pub. L. 111-11, Sec 4001). A central task of CFLRP collaboratives is to develop a shared understanding of desired conditions for forest restoration that is scientifically sound and socially acceptable and to provide collective management recommendations to the U.S. Forest Service.

Table 1. Characteristics of the CFLRP landscapes included in the study. ^aU.S. Forest Service Region: 1, Northern; 3, Southwestern; 6, Pacific Northwest. ^bThe Deschutes project boundary expanded to 104,348 ha in 2013.

<i>Project Name</i>	<i>Collaborative</i>	<i>USFS Region^a</i>	<i>State</i>	<i>National Forests</i>	<i>Area of Landscape (ha)</i>
Four Forests Restoration Initiative	4FRI Collaborative (4FRI)	3	AZ	Apache-Sitgreaves, Coconino, Kaibab, Tonto	971,246
Selway-Middle Fork Clearwater Project	Clearwater Basin Collaborative (Clearwater)	1	ID	Nez Perce, Clearwater, Bitterroot	566,560
Deschutes Skyline Landscape	Deschutes Collaborative Forest Project (Deschutes)	6	OR	Deschutes	52,609 ^b
Southwest Jemez Mountains	Southwest Jemez Mountains Collaborative (SW Jemez)	3	NM	Santa Fe, Valles Caldera National Preserve	84,984
Southwestern Crown of the Continent	Southwestern Crown Collaborative (SWCC)	1	MT	Lolo, Flathead, Helena	586,661
Tapash Sustainable Forest Collaborative	Tapash Sustainable Forest Collaborative (Tapash)	6	WA	Okanogan-Wenatchee	659,621

Ecological reference conditions often play an important role in collaborative planning by helping stakeholders with a diversity of interests to identify appropriate targets or goals for restoration. However, recent analysis suggests that differing perspectives on the utility of, or approach to, reference conditions can pose a fundamental challenge to this task (Urgenson et al. 2017; Walpole et al. 2017). In this article, we examine social perspectives on reference conditions among a diversity of stakeholders engaged in collaborative restoration of fire-adapted forest landscapes in the western United States. We address two questions: (1) What approaches to reference conditions are used by collaboratives to establish restoration targets in fire-adapted forest landscapes? (2) How do diverse stakeholders perceive the benefits and limitations of these approaches?

Methods

We studied six CFLRP projects representing a variety of geographic, biophysical, and social contexts in the western United States (Table 1). Several criteria were used to select collaboratives for this study. All received CFLRP funding in 2010, the program's first funding cycle. Additionally, we selected two from each of three U.S. Forest Service regions (Northern, Southwestern, and Pacific Northwest) to capture perspectives on reference conditions across a range of ecoregions. We interviewed collaborative members, local stakeholders external to the collaborative, contractors (e.g. collaborative coordinators and facilitators), and U.S. Forest Service staff associated with each project. We used a combination of chain referral (Biernacki & Waldorf 1981) and purposive sampling (Palys 2008) to achieve a diverse sample of stakeholders (Table 2).

An interview guide with a predetermined list of questions was developed to ensure comparability among interviews. Respondents were also encouraged to elaborate on or raise

Table 2. Affiliations of interview participants.

<i>Affiliation</i>	<i>No. of Respondents</i>
U.S. Forest Service	23
Nongovernmental organization	19
University	10
Local government (state, county, city)	5
Industry	6
Native American tribal member and/or employee	5
Collaborative contract staff	5
Private consultant	4
Community member/volunteer	4
Other federal or state land management agency	5

additional topics they deemed relevant to the objectives of the study. The guide was tested with two respondents not included in the sample. Interview questions were designed for a broader analysis of the collaborative process (Urgenson et al. 2017). Here, we focus on questions that explored respondent perspectives on developing a shared vision of desired conditions for restoration and the benefits and challenges of using reference conditions to inform that process. Three questions specifically targeted respondent's perspectives on reference conditions:

- 1 Some groups use reference conditions (e.g. historical conditions, an intact system, and/or a modeled ecosystem) as a basis for developing desired conditions. Can you describe how your collaborative identifies and uses reference conditions?
- 2 In your opinion, what are the challenges and benefits of identifying and using these reference conditions?
- 3 Has the topic of climate change been discussed by the group in the context of desired conditions and reference conditions? If so, please describe this discussion.

Table 3. Percentage of interviews in which each type of reference condition was identified. Numbers of respondents are shown in parentheses.

Reference Type	Total (81)	4FRI (15)	Clearwater (12)	Deschutes (19)	SW Jemez (9)	SWCC (12)	Tapash (14)
Historical (pre-settlement)	91	93	100	79	89	100	93
Historical (other reference periods)	2	0	0	0	0	17	0
Contemporary	11	27	0	0	0	42	0
Future	11	0	0	0	0	0	64

Between November 2013 and October 2014, the first author conducted 81 in-depth interviews with 86 respondents (four interviews involved more than one respondent). Interviews were by phone (31%) or in person (69%). Each interview lasted 0.5 to 2 hours, yielding a total of greater than 79 hours of recordings. Participants were assured that data would be treated confidentially, that is coded such that responses could not be linked to particular respondents. We also attended collaborative meetings and examined relevant background documents, including CFLRP proposals, landscape assessments, and National Environmental Policy Act (NEPA) planning reports, to aid the analysis.

Interviews were recorded, transcribed, and analyzed using the qualitative data analysis software, Atlas.ti version 7.5.9 (Muhr & Fries 2004). Interview transcripts were analyzed using an iterative process of open coding (Saldaña 2015) to organize data according to participant's perspectives on reference conditions. Through this process we identified the types of reference conditions used by collaborative groups; we then classified responses into a set of "themes" representing stakeholder perspectives on the principal benefits and limitations of these reference conditions in restoration planning. We tallied the number of interviews in which each theme was mentioned, and expressed this as a percentage of the total number of interviews. We present direct quotations from the interviews to illustrate the themes and to clarify links between the data and our findings.

Results

Based on interview responses and a review of collaborative documents, we found that collaboratives use a variety of approaches to identify reference conditions including historical, contemporary, and future scenarios (Tables 3 & S1, Supporting Information). Historical conditions prior to European settlement (i.e. nineteenth century or "pre-settlement" conditions), or prior to more recent grazing, logging, and exclusion of fire, emerged as the predominant form of reference (Table 3). Consequently, responses describing the benefits (Table 4) and limitations (Table 5) of reference conditions naturally focused on this approach. Stakeholder perspectives on reference conditions were complex. Respondents often described multiple benefits and limitations of reference conditions. Of 81 interviews, 2% did not mention either benefits or challenges, 23% identified only benefits, 30% identified only challenges, and 44% identified both benefit(s) and challenge(s) of historical reference conditions. The frequencies with which particular benefits or challenges were identified within each collaborative group are presented in Tables S2 and S3.

Table 4. Perspectives of CFLRP stakeholders on the benefits of reference information based on historical conditions prior to European settlement (i.e. nineteenth century or "pre-settlement" conditions), or prior to more recent grazing, logging, and suppression of fire. Values are the percentage of interviews ($n = 81$) in which a benefit was identified. See Table S2 for percentages within each collaborative group.

Theme	Percentage
1. Provides scientifically defensible targets	40
2. Helps to identify ecological conditions that are resilient to disturbance	23
3. Facilitates collaborative discourse	26
4. Brings stakeholders together around a common vision	19
5. Provides a visual representation of forest structure	17
6. Provides compelling justification of the need for restoration	15
7. Provides a relatable story and gateway-to-understanding for stakeholders with limited scientific training	11

Historical References

Pre-settlement Conditions. A majority (91%) of interview respondents described historical pre-settlement forest conditions, or conditions prior to more recent grazing, logging, and exclusion of fire, as a primary source of reference information used by their collaboratives (Table 3). Historical data were based on dendroecological analyses of tree rings and fire scars, as well as documentary archives, and included a combination of site-specific forest plots, previous research, and landscape modeling (Table S1). We identified several recurring themes corresponding to stakeholder perceptions of the benefits (Tables 4 & S2) and limitations (Tables 5 & S3) of using these reference conditions to inform restoration of fire-adapted forest landscapes.

Historical reference conditions were frequently perceived to provide scientifically defensible targets for restoration (40% of interviews, Theme 1, Table 4), offering a baseline for understanding ecological change and departure, and serving to neutralize otherwise value-laden discussions about multiple, sometimes competing, resource objectives. As described by a Tapash respondent:

If you don't know what was there, you don't know how to restore it. Everybody says, "Restore wildlife habitat." What do you mean by that? You have to start with some place. The only place you really can defend is the historical reference.

Table 5. Perspectives of CFLRP stakeholders on the limitations of reference information based on historical conditions prior to European settlement (i.e. nineteenth century or “pre-settlement” conditions), or prior to more recent grazing, logging, and suppression of fire. Values are the percentage of interviews ($n = 81$) in which a limitation was identified. See Table S3 for percentages within each collaborative group.

Theme	Percentage
1. Does not align with other current stakeholder values and interests	38
2. Overemphasizes the past rather than thinking about the future	15
3. Generates conflict over different interpretations of reference-condition science	16
4. Results in an overly prescriptive or static approach to setting restoration targets	25
5. Not relevant due to climate change	22
6. Not relevant because the ecosystem has crossed a tipping point or ecological threshold	9
7. Represents an arbitrary or narrow choice of timeframes	20
8. Could lead to over-generalization of stereotypical conditions where local data are inadequate	19

Nearly a quarter of respondents reported that historical, pre-settlement reference conditions help to identify ecological conditions that are resilient to disturbance (23% of interviews, Theme 2, Table 4), as evident by their occurrence within a functionally intact disturbance regime and fluctuating climate. As described by a SW Jemez respondent:

The [historical pre-settlement] reference condition is a point where we know that these habitats existed and that these forests withstood a lot of disturbance.

Other perceived benefits include facilitating collaborative discourse (26% of interviews, Theme 3, Table 4) and bringing stakeholders together behind a common vision (19% of interviews, Theme 4, Table 4). For example, interviewees reported that historical reference information fostered a shared language and understanding among collaborative members. As described by a Deschutes respondent:

There is a comfort if we feel like we're getting close to what the historical conditions used to be like. It gives us that dialog, that kind of middle ground, a baseline that we can discuss, talk about in the same way.

Historical reference conditions were also perceived to facilitate social learning and comprehension of ecological information. Respondents described their importance for public education and outreach because they provide a mental image or visual representation of forest structure (17% of interviews, Theme 5, Table 4), compelling justification of the need for restoration (15% of interviews, Theme 6, Table 4), and a relatable story or gateway-to-understanding for stakeholders with limited scientific training (11% of interviews, Theme 7, Table 4). As described by a Clearwater respondent:

I believe people without resource knowledge and without resource training, can relate to that [historical] information if it's presented right.

In contrast to these benefits, stakeholders identified a number of limitations or challenges to restoration associated with historical reference conditions. Interview respondents described three specific challenges in which an emphasis on historical reference conditions engendered conflict (Themes 1–3, Table 5). The most common occurred when reference conditions were not perceived to align with other current stakeholder values and interests (38% of interviews, Theme 1, Table 5). Responses from collaborative stakeholders illustrate multiple situations in which historical references were perceived to conflict with other social values. As described by a SW Jemez respondent:

We try to use [historical reference conditions] ... but that's not necessarily where we are going, largely because of social values. Grazing is going to continue on the forest, people are going to continue to live around the forest, there are too many other influences. So we have to take in the social context of what we are trying to do and realize it's not possible to recreate [historical] conditions.

A respondent from the Deschutes described the concern that restoring to historical conditions would adversely affect habitat for wildlife dependent on closed-canopy forest:

What you're looking at now is a really wonderful wildlife habitat. So should we be cutting up existing wildlife habitat, even though the trees may not have been there according to HRV [historic range of variability] ... you need to keep some of our good existing habitat now, no matter what HRV says.

A respondent from the SWCC described a tension between historical reference conditions and the need to address public-safety concerns:

Some people think we should use historical range of variability and that's the way to go but I don't necessarily agree that that's the whole picture ... there's a social side. There's public safety. There are other things that would prevent us from ever getting effective historical range of variability.

Finally, a respondent from 4FRI described an inherent conflict between managing for historical conditions and the aesthetic attachment of some stakeholders to denser forests stemming from personal memories and expectations:

You get people who are coming up during the summertime to sit in the cool pines. What happens when there is only a tenth of the cool pines that there are right now?...People have an idea of what

these forests are supposed to look like and they have nothing to do with historical conditions or pre-European conditions or anything like that. It's what they had been seeing over the last 10 years, 20 years that they've been coming up here.

In circumstances where restoring historical conditions would not accommodate other social values or goals of management, respondents emphasized the importance of open and transparent communication about trade-offs in management decisions based on historical references versus contemporary pressures.

Additionally, historical reference conditions engendered conflict when they were perceived to overemphasize past relative to current or future conditions (15% of interviews, Theme 2, Table 5). Respondents also described conflict arising from differing interpretations of reference-condition science (16% of interviews, Theme 3, Table 5). This occurred when collaborative members debated what constitutes reliable reference information, defending their views with conflicting evidence from different scientific studies of historical conditions. As described by a 4FRI respondent:

There's a variety of opinions in the collaborative of science [on historical reference conditions] and whether it's smoke and mirrors or whether it's true rigorous peer-reviewed science. Much of that science is not accepted by a few of the folks. So, how can you move forward with desired conditions based on meaningful measures of evidence if the group doesn't accept that [science]? That's a head-scratcher for some of us.

In other critiques, respondents expressed concerns that historical reference conditions fail to capture the dynamic nature of ecosystems and questioned their appropriateness as restoration targets for current or future conditions (Themes 4–6, Table 5). For example, one quarter of respondents noted that historical reference conditions can result in overly prescriptive or static approaches to setting restoration targets (25% of interviews, Theme 4, Table 5). Rather than attempt to replicate historical forest structure, these respondents often preferred to emphasize restoration of ecosystem processes or functions, for example, through reintroduction of wildfire. As described by a SWCC respondent:

It's really easy for reference conditions to reinforce an understanding of what we're trying to get to is a static and equilibrium system, and that is ... absolutely not the case.

According to some respondents, historical, pre-settlement reference conditions are no longer relevant due to the inherently dynamic nature of ecosystems and to ongoing changes in their structure and composition (22% of interviews, Theme 5, Table 5), or because the ecosystem had crossed a tipping point or ecological threshold that prevented reversal (9% of interviews, Theme 6, Table 5). A key example of the latter relates to the prominence of western white pine (*Pinus monticola*) in the historical landscape of the Selway-Middle Fork Clearwater Project.

In portions of the Clearwater Basin, white pine made up more than half of the forest overstory. Introduction of a non-native blister rust in the early 1900s severely reduced its abundance and, although rust-resistant trees remain, white pine is no longer dominant. Given limited ability to reestablish former densities, respondents questioned the value of historical reference conditions to guide restoration. As described by a Clearwater respondent:

What we really can accomplish is never going to take us to our reference condition. White pine is a very extreme example but our reference condition would be a 50% to 65% composition of white pine. We are never going to get there.

Finally, respondents were apprehensive about using particular historical, pre-settlement reference conditions because they were perceived to represent an “arbitrary” or narrow choice of timeframes (20% of interviews, Theme 7, Table 5), or because they could lead to over-generalization of historical stereotypes where more appropriate local data were limited (19% of interviews, Theme 8, Table 5). For example, there is an abundance of historical information on dry forests characterized by frequent, low-severity fire, but a paucity of similar information on moister, mixed-conifer forests characterized by greater variation in tree density and fuel conditions. Respondents were concerned that uncritical extrapolation of historical reference conditions from one forest type to another would result in inappropriate targets for restoration. Similarly, within individual forest types, respondents were concerned about loss of variation in forest characteristics if management prescriptions were based on a narrow range of reference conditions, particularly in large or environmentally diverse landscapes. As described by a Tapash respondent:

We have this urge for this oversimplification of it, we are really good at talking about that open ponderosa pine stand ... but we are terrible at talking about the fact it was messy, it was mesic and it was never exactly like the simplified version we keep presenting.

In sum, despite variation in collaborative group characteristics and landscape contexts, diverse stakeholders share common perceptions of the benefits and limitations of historical pre-settlement reference conditions. Collaborative groups navigate often complex, and sometimes contradictory, viewpoints to determine the extent to which historical reference conditions will inform goals for ecological restoration in fire-adapted forest landscapes.

Other Historical Reference Periods. Several respondents from the SWCC described historical reference conditions that broaden the temporal scale of consideration beyond the pre-settlement period (Table 3). Specifically, these respondents described reference information based on vegetation models that project back to the Medieval Climate Anomaly (or Medieval Optimum, circa 1,000–700 years BP). This period of warmer, drier climate was perceived to be more analogous to projections for the near future than the climate of the

pre-settlement period, which occurred during the cooler and wetter climate of the Little Ice Age (600–200 years BP). As described by a SWCC respondent:

If it's going to be really warm and dry like it was during the Medieval Optimum what might be the future for us?...We've been taking a look at time steps way back ... versus taking a look just in the mid-1800s, which doesn't have that long-term view. It's really interesting to look at that because it gives you some sense of what the forest community might look like in the future.

These stakeholders believed that selecting a reference time period based on its resemblance to the projected future climate was a more appropriate means of establishing reference conditions, but one that still bridged between historical and future conditions.

Contemporary References

Respondents from two collaboratives, 4FRI and SWCC, described reference conditions based on characteristics of nearby forests that had not been harvested or grazed, and/or in which fire regimes were minimally altered or restored (Table 3). Where available, these contemporary references were thought to provide valuable opportunities to examine natural patterns of ecological variability. For example, a SWCC respondent described an attempt to combine contemporary references with historical information to better understand the role of fire in structuring local forest ecosystems:

It's a blend of modeling historical conditions and also the wilderness that's in the landscape and right next to the landscape. I think everyone recognizes that it's [the wilderness] a little different because it's generally higher elevation, but it's a similar forest type. There's been fire in [the wilderness area(s)] that's for sure, a lot of it...it serves as a reference.

However, for many landscapes, respondents reported that contemporary reference information is limited, difficult to find, or representative of a narrower or a different set of ecological conditions (e.g. differing soil type or elevation) than the focal ecosystem. As described by a 4FRI respondent:

[Contemporary reference conditions] just don't exist. You've got a couple acres here, a couple acres there. The best we have is on a different soil type so we can use it as a surrogate for what this [the restoration site] should look like ... but it probably shouldn't look like that because it's a different soil type.

Thus, in considering the potential value of contemporary references, respondents acknowledged the need to be deliberate about the types of information available and the extent to which it can be effectively extrapolated.

Future References

Among the collaboratives in our study, the Tapash was unique in using future reference conditions to inform targets for restoration (Table 3). Respondents described modeling the range of future variation from “climate-analogue” sites, that is contemporaneous sites representing warmer and drier conditions, as plausible references for anticipated future climates. Use of future references enabled the group to step back from a focus on historical conditions and to frame discussions about restoration in the context of a changing future environment. A Tapash respondent described benefits of this approach:

It got people to quit thinking about just the past and accept that ... these systems are not stagnant in time and they are changing. We have some assumptions about the future, however you feel about the issue of climate change, that we already see occurring and we have to consider them. I think it removed us from thinking of something nostalgic that sometimes we did oversimplify and got us to look ahead to what does resiliency mean, not just restoration.

In contrast, the remaining collaboratives did not identify future conditions as references for their groups (Table 3). However, projected future conditions were often mentioned in interviews and collaborative documents as important justifications for restoration. Moreover, several collaboratives held events that included climate change adaptation workshops as opportunities for joint-learning and discussion (Table S1). Despite recognizing their importance, respondents provided two reasons for not incorporating future reference conditions directly into restoration planning. First, targeting historical conditions that developed over long time periods and under changing climates and disturbance regimes was commonly perceived to produce landscapes resilient to ongoing and future changes in climate and other environmental factors. Second, future conditions were described as a potentially contentious topic accompanied by high uncertainty (and thus risk) due to the ecological complexity and technical challenges of modeling future forest landscapes. For example, a Deschutes respondent described the hesitancy to address future conditions directly:

It [future conditions] is not something that people are looking at ... It's sort of an elephant in the room. In terms of restoring the health of the forest the subtext is that we are doing what we can to go back to a stasis that hopefully is sustainable. How that is impacted by global warming and climate change, I think it's yet to be seen.

Thus, rather than grapple with uncertainty and risk inherent in projections of future conditions, most collaboratives chose to instead focus on historical references as areas of greater agreement.

Discussion

Given widespread human influence on ecosystems and projected changes in environmental conditions, setting appropriate reference conditions for restoration is a fundamental challenge. Our findings suggest that social perspectives on ecological reference conditions are complex, with a majority of stakeholders recognizing both benefits and limitations of various approaches to reference information. Nevertheless, collaboratives are navigating trade-offs in these approaches and developing innovative strategies to help foster agreement on targets for restoration (Urgenson et al. 2017). Many of the perspectives and strategies identified in this study of western forests in the United States are likely to be relevant to other fire-dependent ecosystems and, more generally, to systems that have been heavily altered by industrial human influence.

Despite long-standing debates on the role of historical information in setting targets for restoration and ecosystem management (Millar & Woollenden 1999; Stephens et al. 2010; Thorpe & Stanley 2011), collaborative restoration of fire-adapted forest landscapes in the western United States continues to rely heavily on historical reference conditions. At the same time, stakeholders recognize the value of contemporary, relatively undisturbed forests as references, although many CFLRP stakeholders felt that contemporary reference sites are lacking or compromised due to legacies of past logging, grazing, and fire exclusion. Most collaboratives did not directly incorporate future conditions into decision-making, despite awareness that environmental change, and climate change in particular, may affect management outcomes. Perceived barriers to the use of future conditions include difficulty or uncertainty in predicting future forest conditions and a desire to avoid debates about its causes. This finding echoes previous literature on barriers to future and climate-related adaptation (Lorenzoni et al. 2007; Moser & Ekstrom 2010; Gifford 2011) and underscores the need to support strategies that enable collaboratives to address future conditions more directly.

Conditions prior to European settlement (i.e. nineteenth century or “pre-settlement” conditions), or prior to more recent grazing, logging, and fire exclusion are the predominant form of reference information used by collaborative groups. Stakeholders perceived that the use of historical reference conditions provides a science-based framework to develop a common vision and to gain social understanding and acceptance of the underlying need for restoration. This finding is consistent with a large body of research, management, and policy that relies on historical reference conditions to understand how forest ecosystems have changed over time and to guide management that fosters greater resilience (Morgan et al. 1994; Noss et al. 2006; Keane et al. 2009; Churchill et al. 2013; Haugo et al. 2015).

At the same time, collaborative stakeholders identified key limitations or methodological challenges of using historical conditions as a reference. The most frequent challenge occurred when restoration objectives were perceived to place greater emphasis on historical conditions than on other current socioeconomic or political viewpoints or goals of management (e.g. public safety, wildlife habitat, or aesthetics). Respondents

recognized the value of historical conditions as baselines for change and targets for restoration, provided there was consideration of the social acceptability of these outcomes. This challenge reflects a need to develop practical and effective guidelines for incorporating social aspects of restoration, along with its technical and ecological aspects, in the planning and evaluation process (Shindler et al. 2002; Perring et al. 2015). For example, collaborative groups are developing strategies for social learning and participatory science as a means to frame issues, to establish legitimacy to both stakeholder values and ecological science as bases for decision-making, and to analyze trade-offs in management objectives (Urgenson et al. 2017). In contrast, foundational documents such as the Society for Ecological Restoration International’s *Primer on Ecological Restoration* (SER 2004) focus heavily on ecological reference conditions but largely overlook the importance of other social values in setting targets for management interventions (Shackelford et al. 2013; Wortley et al. 2013).

Several of the stakeholder-identified limitations highlighted in our study lie at the root of long-standing debates on whether and how past conditions should inform the objectives of restoration, or of land management more generally (Landres et al. 1999; Moore et al. 1999; Swetnam et al. 1999; Higgs et al. 2014). Temporal change is inherent in ecosystems and, accordingly, reference conditions should be framed in the context of spatiotemporal variability (Veblen et al. 2012). Stakeholders questioned the relevance of historical references in systems that exhibit nonequilibrium dynamics or that have transitioned to alternative states. There is a large and growing literature (both conceptual and empirical) on regime shifts, alternative stable states, and nonanalogue systems (Suding & Hobbs 2009; Hobbs et al. 2014). Whether these ecosystem transitions reflect changes in climate or disturbance regime, invasion by non-natives, or internal feedbacks, reversal to historical conditions may be extremely difficult or impractical.

Finally, empirical data on historical conditions are lacking for many forest landscapes and stakeholders expressed concern about generalizing from one system (e.g. dry ponderosa pine forests) to others (e.g. moist mixed-conifer forests). These concerns highlight a critical need to acknowledge the extent to which reference information can be effectively extrapolated (Schoennagel et al. 2004; Schoennagel & Nelson 2011), and to focus scientific research on ecosystem types for which reference information is limited or lacking.

Explicit recognition of the perceived limitations of reference conditions is critical in the design and evaluation of collaborative restoration initiatives that are both scientifically sound and socially acceptable. For example, to address the concern that historical conditions are inappropriate references for current or future landscapes and climates, members of the SWCC broadened the temporal range of consideration to include the Medieval Climate Anomaly (900–1,300 CE), a time of warmer climate more analogous to that of the near future (Bollenbacher et al. 2014; Millar 2014). Extending the temporal range of historical reconstructions can be difficult, however, due to the loss of ecological evidence over time. Thus,

there is a need to develop reference conditions using multiple methods, types, and sources of information (Swetnam et al. 1999). To address the challenges of incorporating future conditions directly into decision-making, the Tapash Collaborative uses climate-analogue sites (Gärtner et al. 2008; Hessburg et al. 2013) as consistent means to define and quantify future conditions. This allows the group to frame discussions of reference conditions in terms of both restoration and the potential to enhance resilience of forested landscapes to the direct and indirect effects of predicted changes in climate (Keane et al. 2009).

In an era of rapid anthropogenic change, understanding social perceptions of reference conditions is critical for restoration scientists and practitioners who work in collaboration with diverse groups of stakeholders at increasingly large spatial scales. Despite ongoing debates over the relevance of historical information in restoration, our study suggests that historical references continue to play an important role in the practice of restoration. Management that moves landscapes toward historical conditions was generally perceived as enhancing the potential for resilience under changing climate and disturbance regimes. A diverse range of stakeholders acknowledged important benefits of reference conditions as targets for restoration, but also identified limitations. Collaborative groups are developing strategies to address these limitations by considering past, present, and future conditions; by identifying reference periods more similar to current and projected future climate; and by balancing ecological objectives with social values and needs in restoration planning. These insights can be applied to benefit future restoration efforts and, more broadly, to enhance understanding of the reference condition concept.

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Supporting Information

The following information may be found in the online version of this article:

Table S1. Collaborative approaches to identifying and using reference conditions in fire-adapted forest landscapes.

Table S2. Perspectives of CFLRP stakeholders on the benefits of reference information.

Table S3. Perspectives of CFLRP stakeholders on the limitations of reference information.